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Urban tunnel systems for conveyance and storage of storm- and wastewater: features, classification, and modelling

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Features

Tunnels have been integrated in many urban drainage systems as an effective solution to combined sewer overflow (CSO) and flooding. The substantial growth of the urban population, the greater proportion of hard surfacing, and the higher frequency of intense rain events have drastically increased flows in the drainage network. When the design capacity is exceeded, excess water overflows to the natural recipients or backs up into the drainage system, causing street flooding.

Originally designed for CSO interception in combined sewers (Figure 1), tunnels have also been integrated in separate sewers. In all cases, their defining feature is the ability to convey and store large quantities of water in urban areas, with minimal disruption at the surface level and attractive cost-benefit ratios.

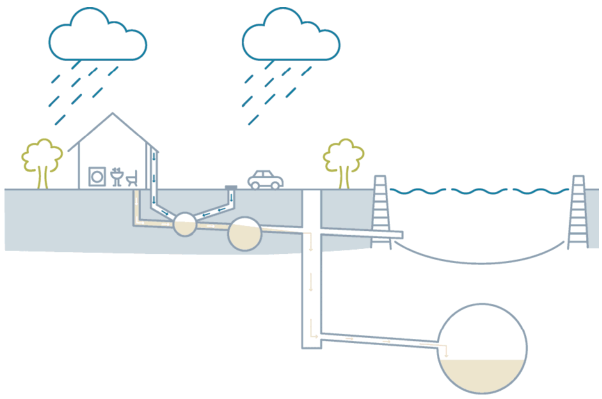

Figure 1 Scheme of a tunnel for interception of combined sewer overflow (adapted from www.tideway.london)

Table 1 Overview of case studies, including location, project name, type of water conveyed and key benefit.

Location	Project name	Water conveyed	Key benefit
Abu Dhabi, UAE	*Strategic Tunnel Enhancement Programme*	wastewater	Greywater reuse
Chicago, IL, USA	*Tunnel and Reservoir Plan*	combined	Pollution prevention
Copenhagen, DK	*Østerbro Stormwater Tunnel*	stormwater	Couldburst relief
Kuala Lumpur, MY	*Stormwater Management And Road Tunnel*	stormwater	Vehicular traffic
London, UK	*Thames Tideway Tunnel*	combined	CSO reduction
Mexico City, MX	*Tunnel Emisor Oriente*	combined	Flood prevention
Singapore, SG	*Deep Tunnel Sewerage System*	wastewater	Land use optimisation

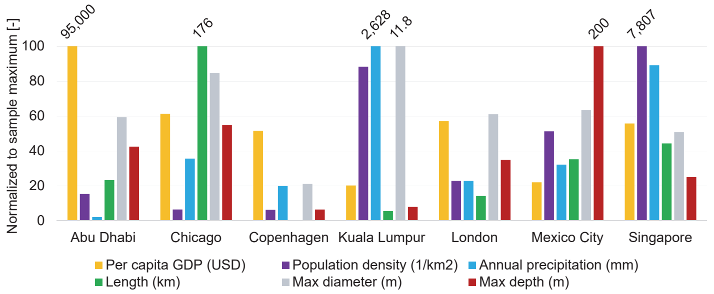

Figure 2 Relative comparison of case studies based on key catchment and design parameters.

Classification

The selected case studies (Table 1) represent the variety of catchments in which tunnels have been integrated. Three design parameters (cumulative length, maximum internal diameter, and maximum depth) were set against three catchment parameters for an economic, demographic, and climatic characterization: per capita gross domestic product (GDP), density of population, and average annual precipitation.

The analysis in Figure 2 shows that it is a combination of the investigated (and other) catchment parameters to determine the specific design requirements of a tunnel. Therefore, we suggest a classification of tunnels solely based on the type of water that needs to be conveyed: wastewater, stormwater, or a mixture of the two (combined).

Modelling

Excavating large tunnels to expand the storage capacity of the drainage network is not enough to future-proof urban drainage systems, if this supplementary volume is not adequately monitored and controlled.

Many numerical models exist that are capable of simulating the hydraulic behavior of tunnel systems. When used for control purposes, however, models need to be kept in touch with reality based on observations from the system and, furthermore, need to provide quantitative uncertainty estimates. We will investigate how to accomplish this using e.g. ensemble based data assimilation methods (Figure 3).

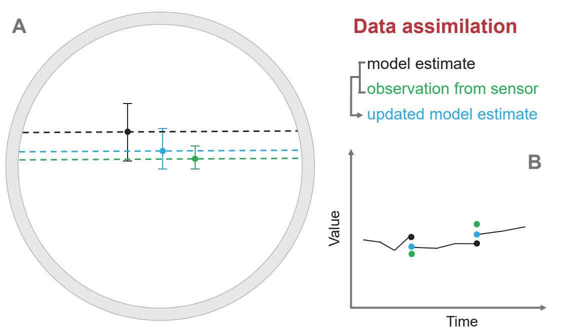

Figure 3 Using data assimilation to update model estimates in space (A) and time (B) with sensor observations.

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